

## preFAB\_lab

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### Abstract

*"We're not builders, we are manufacturers."*

Bill Levitt, Founder of Levittown, New York

Levittown, New York was created between 1947 and 1951 in response to the housing needs of the military infantry returning from World War II. Levittown is recognized as the first planned community and is an archetype for suburban development in the United States. For developer Bill Levitt, it was also an experiment in low-cost mass-produced housing inspired by Henry Ford's automotive assembly-line production model. Ford's assembly-line invention transformed the custom fabrication of automobiles into a model that is streamlined, standardized, more efficient, and more reliable and ultimately a more affordable product. This efficiency was primarily achieved through a conveyor system, which moved the "product" to stationary workers assembling standardized components. Levitt re-envisioned this process; inverting the stationary/non-stationary relationship such that the building trades actively moved "down the line" to the housing product. The Levittown development and its mass-produced houses was criticized for a lack of vision by the architectural community, but is now viewed as a successful experiment. Bill Levitt's bold experimentation and re-envisioning of the Ford assembly line was the inspiration for a graduate level studio, the preFAB\_lab.

### The Challenge

The preFAB\_lab explored the territory of affordable and sustainable housing and challenged normative building practices, critically investigating prefabrication methods. The studio's design objective was a holistic

integration of two distinct building typologies: the single-family house and manufactured housing. The question "how was it made" was diametrically tied to "how should it be assembled." Architectural solutions combined the theoretical, technological and environmental aspects of design and fabrication. Areas of studio exploration included component integration, production technique, manufacturing time, sequence of fabrication/trades, and incorporation of digital input and output tools. The success of a design solution was critically evaluated based upon these explorations.

Similar to Levittown, the proposed project site contained both light industrial and medium density residential lots that provided an opportunity for integrated live/work or mixed-use development. Each student conducted extensive research into modular and prefabricated systems both within and outside the normative building industry. Students were tasked to develop a prefabrication strategy and test it through multiple housing prototype designs. This paper will present three innovative projects of preFAB\_lab, which re-envision the ideals of prefabrication, materiality and image to create new strategies for pre-fabrication from factory production to housing unit to site integration.

### preFAB\_lab

Modern Architecture has long been attracted to prefabrication and its ideals of efficiency, optimization, accuracy and incorporation of technology. However, the interpretation and implementation of these principles is an "arduous task of management" and examination of its "operation, machine development and their coordination." Despite the noble intentions of modernity's most prolific architects, the dream of "factory made house" within the American domain of architecture has been less than successful. Modern architecture has tried to create lightness and efficiency both aesthetically and formally through various prefabricated methods, but without always understanding the operation's management system (design + fabrication) as well as the social and business markets that drive them. This system knowledge includes understanding material, product and information flows and how to "taylorize" them for specific needs. It also must include an understanding of business practices and how they can be harnessed and transformed (if at all) to fit the production model towards success with

its ultimate consumer. preFAB\_lab, a graduate level studio at Montana State University, took the design challenge to critically explore prefabrication as a viable system of concept to implementation and business practice to address the need for affordable housing in the Gallatin Valley of Montana, where housing costs have risen at an alarming rate and made obtaining the “American Dream” exigent.

Despite its limited achievement in architecture, prefabrication outside the architectural milieu has been successful in industries such as the automobile and airplane where design process through fabrication has been transformed and its resulting products made “lighter” and more efficient. In Jon Thackara’s book *In the Bubble*, he states, “Eighty percent of the environmental impacts of the products, services, and infrastructures around us is determined at the design stage.”<sup>1</sup> This precept holds especially true in the building industries. Lightness is an ideal that reaches beyond the physical domain of form and material substance, and should be sought in the foundations of design. Nowhere is this ideal of “lightness” as a design system more apparent than at Boeing Airlines and their LEAN production system.

As part of the research conducted during the semester, the preFAB\_lab studio went to Seattle, Washington to visit the Boeing Plant in Renton, WA, which produces the Boeing 737 airplane. The studio learned how Boeing transformed an already successful product through the redesign of their current business model and mode of operation, which is the LEAN system. *Kaizen* is a Japanese term for continuous cycle of incremental process improvement. The identification of waste within a system starts with the process of continuous process or *kai-zen*. The LEAN system focused on the entire value stream of the Boeing operation from raw material to finished product. It covered areas of space, labor, energy, material, time, transportation and safety. Through this evaluation, Boeing developed a guide of 9 Tactics to a LEAN System. Tactics included understanding how value systems flow, mapping the entire production flow from raw material to finish project, identifying values in the system and how they developed. Tactics also included documenting and balancing the distribution of work; even redesigning the manufacturing process and the tools to improve efficiency and performance.

My own research of prefabrication has been greatly influenced by personal interests in the design construct of “lightness,” through the lens of material research, design methodologies and building performance. Beyond the associative quality of weight, lightness is a holistic framework for design that fundamentally questions how design constructs engage the built and natural environments respectively. Learning the design model of Boeing has not only expanded my architectural beliefs but also influenced my pedagogical objectives as an educator filtering largely into the studio goals of the preFAB\_lab. Operating on the principles posited by architect and theorist Sanford Kwinter, architecture is viewed principally through its operation. The graduate studio rejected traditional studio ideals driven by building typologies, and instead studied the principles of LEAN to view architecture principally through its operation (what it does); focusing on design, fabrication and performance based strategies that inspire and direct decisions and experimentation into areas of lightness, energy performance, material resourcefulness and product delivery.

***“We’re not builders, we are manufacturers.”***

Bill Levitt, Founder of Levittown, New York

Created between 1947 and 1951 as a response to need for housing GIs returning from World War II, Levittown, New York is considered to be the first planned community and the archetype for the suburban development in the United States. To developer Bill Levitt, however, Levittown started as an experiment in low-cost mass-produced housing. The innovation of Levittown was Levitt’s reinvention of Henry Ford’s world successful assembly-line production as a mode to produce architecture. Ford’s assembly line model was used to create better built automobiles more efficiently and make them more affordable. This was achieved by relying on the “product” to be moved down a conveyor system to stationary workers. Levitt’s vision, however, redesigned the process by inverting the operation of the system by having the workers of the various building trades move “down the line” to a stationary product – the individual house. Though the development and the housing stock of Levittown has largely been criticized by architects for its “lack” of vision, it was by and large a successful experiment. It is Levitt’s “experimentation” and bold re-envisioning of an existing successful system that serve as inspiration

for the studio and the opportunity to explore principles of lightness and prefabrication.

The preFAB\_lab studio used Levitt's vision as a starting point for thinking about and inventing lightweight efficient prefabricated design strategies. Rather than focusing on foundational research only at the beginning, research methodology was fully intertwined into the studio process. The research drove an iterative process of design, exploration, and vetting of ideas. Students were encouraged to ask deeper questions of process and discover new ways of working. The students researched numerous prefabrication and emerging building practices and case studies. The beginning research was a critical interrogation of the value of the prefabricated building systems, developing philosophies that merge artistic constructs with machine construction. This merging of principles led each student to develop a prefabrication strategy that would be tested and evolved through prototyping housing units. Three innovative projects from the studio will be presented.

### Project 1

The PAD+ house is a bold reinvention of an old manufacturing archetype, General Motors Corporation, into a new paradigm for light modern customizable prefabricated housing. The site was a former GM Auto plant in Fresno, CA (now closed) that would serve as the context for the prefabricated production design component. Reusing the maligned Fresno facility would save embodied energy resources required to build a new manufacturing facility and could incorporate available machine technology of the industry. Capitalizing upon similar technology and existing worker skills to make many automobile components, the facility would serve as surrogate to fabricate lightweight steel frame and skin components that could be shipped to a site within a NASCAR size semi-tractor trailer truck and then deployed [Fig. 1]. The NASCAR size semi-tractor trailer trucks are the largest scale truck allowed on the highway system, and carry multiple cars in addition to containing sleeping quarters and offices. The trucks could be redesigned to incorporate a small crane and open up to deploy the building components. The design consisted of key standardized components of foundation, steel frame/platform, and customized components of interior modules and range of stylized perforated steel skin panels.

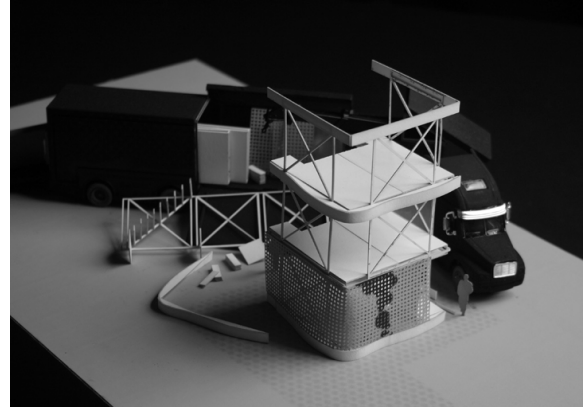


Fig. 1. Model of PAD+ home

The branding concept of GM plays a similar and important role for the modular units; like buying a car online, a homeowner could select various components and combinations of colors via an interactive webpage to order their "personalized General Motors prefabricated home" [Fig. 2]. This strategy could be considered "kitsch" product design and beneath the role of architecture, but it is the ability to "customize," in applications of surface, color and component design that is key to connecting with the end-user and that has eluded other architectural attempts. *Is buying a home like buying an iPod? PAD+ home* postulates that if prefabricated housing is to be successful it must address the consumer culture, connect to buyers' interests, and produce a "high quality" product that has the marketing appeal of the latest Audi sports car. The potential success of the PAD+ home was fortified by the re-visioning of an underutilized manufacturing system of General Motors that changed the design and marketing focus while capturing the existing technology, knowledge and instruments of fabrication to create a customizable, affordable, lightweight and effective building system.



Fig. 2. interactive webpage of PAD+ home by GMC

## Project 2

Montana is among the nation's leaders in spring wheat production in the United States. The climate and good soils of Northern Great Plains states, such as Montana, make it an ideal location to grow the crop. The land has given rise to successful family farms, which have grown into flourishing businesses such as Wheat Montana Farms. Started in Three Forks, Montana, Wheat Montana is a classic business flow model for agricultural practice: encompassing planting to harvest to production of bakery products to distribution centers across the United States. *Could a "from the earth to product" of wheat be re-envisioned for a viable prefabricated building components?* This questioning became an area of investigation for Project 2.

Within residential wood-based construction, Structurally Insulated Panels, or SIPs, are becoming a more common practice given their superior strength, dimensional stability, and thermal performance. Most SIPs use an Expanded Polystyrene (EPS) core that has been deemed environmentally problematic because of its use of chlorofluorocarbons (CFCs) in the manufacturing process, which contribute to the depletion of ozone. However, products such as Agriboard™, which use wheat straw for its core rather than EPS, have been recently introduced into the market place.<sup>2</sup> Agriboard™ is produced in wheat producing states such as Kansas and Texas and over 80% of the panels consist of straw, a waste product leftover after the grain has been harvested. Project 2 proposed a year-round wheat production and wheat straw Structural Insulated Panel facility with Wheat Montana as its franchise developer for a site in

Manhattan, Montana. Influenced by the round-crop circle formations created by pivot irrigation seen in the Gallatin Valley, the site was redesigned to grow wheat for the production of the wheat straw panels.



Fig. 3. Project 2 prototype

The wheat would be planted in the circular shaped fields, irrigated through center-pivot irrigation, harvested and then stored to dry for later use. A new SIPs production facility would anchor the end of the flow line and produce wheat straw insulated structural panels that would be used to construct the prototype housing units. After the wheat is harvested for flour, the bulk wheat straw, stored at one end of the facility, would be collected, moved through the manufacturing facility and transformed into custom sized and shaped structural panels. The prefab housing types vary in unit size and were developed with rounded exterior walls, departing from the standard mold of the rectilinear box form that dominates prefabrication. It highlights the innovative capability and flexibility of SIPs fabrication. Influenced by rounded vernacular structures such as grain silos, this prototype created a spatial experience that directed light, filtering down the walls from windows above. Influenced by the operation of Montana farming, the design and fabrication of the homes, each named after a type of wheat, are connected to the land and a new stewardship of its cultivation. [Fig. 3]

### Project 3

One criticism of prefabricated housing is that it lacks regional influence, pursuing a “banal” universal aesthetic, which can be found in attempts by several contemporary architects. The use of inappropriate or unfamiliar materials and formal choices makes some modern prefab less appealing to the consumer. This is not to imply that housing has to conform to a regional “style” or vernacular, but its conceptual strategy could be influenced by a region, yet remain chiefly modern. Montana is a rural state where iconic agricultural structures such as grain-bins and corrugated metal structures decorate its vast open landscape. The forms are ornamentally unadorned, skillfully pragmatic and efficient in material, scale and form. These values of efficacy influenced the development of Project 3’s prefabrication strategy. Through researching local corrugated metal manufacturers and the material process of forming corrugated metal sheets, Project 3 set out to expand and discover new form/material strategies for a traditional “off-the-shelf” material such as corrugated metal. Rather than restructuring a sheet metal facility, a new metal panel prefabrication facility would be augmented through new tools that could form more complex curvilinear panels. These new panels could reshape traditional agricultural grain bins and Quonset huts into modern open-tube shells that would be assembled on-site through large overlapping corrugated metal panels, nested and stacked, and designed to expand and grow with the needs of the user [Fig. 4]. This strategy required a critical investigation of the sheet metal forming process; how steel sheet material shrinks, deforms and changes shape drove much of the conceptual understanding of form [Fig. 5]. Small study models using a 3D-printer were created to study how the simple forms could be shaped, proliferated and organized on the skewed North-South alignment of the site.

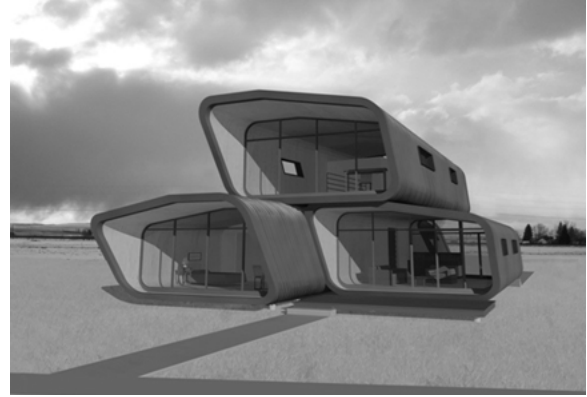


Fig. 4. Rendering of stacked prototypes

Prefabricated housing has not always succeeded in the ease of final deployment or assembly impact to the site. For instance, the Lustron Home, a lightweight steel structure and enamel-coated steel panel kit-of-part system, was created by businessman Carl Gunnard Strandlund. His company patented enamel-coated steel products and hoped to use this system to create housing steel components that were maintenance free, delivered in pieces and assembled on site. Over 2500 Lustron houses were built nationwide, yet its chief demise was its technical assembly that consisted of over 30,000 small parts and took hundreds of hours to erect, making it far more expensive than originally intended. Lessons learned from the Lustron strategy of site assembly became a design problem for Project 3 to reduce the physical and technical impact and complexity on site. The housing unit assembly is broken into four large overlapping segments (two sides + top and bottom) that are shipped to site and bolted together. Large slab components were comprised of smaller sheets accurately cut through the assistance of a large 3-axis CNC-router; sheets were assembled in an overlapping pattern that was diagrammed and digitally coded into the panels [Fig. 5]. The larger panels could be stacked on a flatbed truck, shipped to the site and assembled.

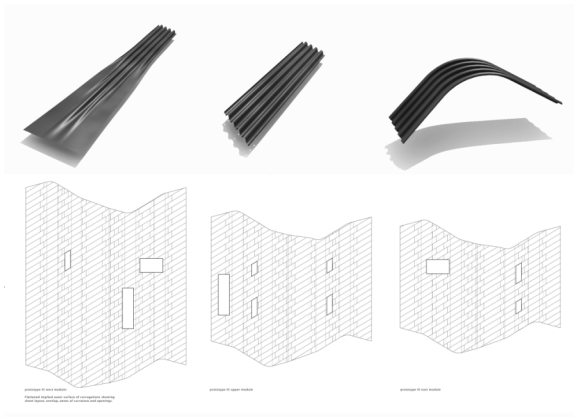


Fig. 5. Deformation studies of steel (above) CNC flattened cut diagrams (below)

The foundation work would be limited to a series of piers and steel beams that supports the stacked units. This reduces the site impact and the cost of foundations and slabs, which is critical in a northern climate such as Montana that has a narrow construction window with over 80 inches of snow annually. Also, the system does not require a seamless translation of foundation to building, which easily accommodates potential site discrepancies.

## Conclusion

The extensive preFAB\_lab research provides various perspectives from which to question, analyze and test concepts. The history of prefabricated housing and its architectural collaborators have pursued two distinct paths: (1) focusing on the formal, material and aesthetic conditions of a house without successfully resolving the technical aspects (fabrication and site assembly) in an efficient or cost-effective manner or (2) in the case of Konrad Wachsmann's "Packaged" house and other similar contemporaries, the concept is usurped by an inability and unwillingness, or possibly ego, to resolve their own ideals.

The preFAB\_lab studio as a laboratory blurred any distinction between the "artistic construct with the machine construction"<sup>3</sup> of prefabrication to discover new modes of design. Learning from the value and effectiveness of Boeing's LEAN system, the students' design work, through carefully developed design goals, interrogated alternative building practices of material, information flows and fabrication tools. Following the value approach of LEAN, students discovered solutions and created tactics that redefined prefabrication practices that

meet their goals. Rather than engaging innovation for the sole purpose of originality (potentially ignoring precedence), the preFAB\_lab innovated by embedding new strategies and approaches within a current system. Prefabrication in this laboratory was not revolutionary. Architecture should challenge prefabrication by engaging the ideals, beliefs and working methods within society to effectively manage and direct prefabrication. To be innovative in prefabrication, architects must fully command material, information and technological flow, as well as more effectively recognize the social and business values of design for broad public connection.

## Notes

<sup>1</sup> Hebert, Glibert, The Dream of the Factory made House, p. 3.

<sup>1</sup> Western Organization of Resource Councils, <http://www.worc.org/index.html>

<sup>1</sup> Davies, Colin, The Prefabricated Home, p. 59.

<sup>1</sup> Ibid.

<sup>1</sup> Thackara, John, In the Bubble: Designing in a Complex World, The MIT Press, 2005.

<sup>2</sup> Agriboard Industries, <http://www.agriboard.com/>

<sup>3</sup> Guillén, Mauro F., The Taylorized Beauty of the Mechanical, p. 31.